

A REVIEW OF CURRENT BARRIERS (REAL AND PERCEIVED) TO OFF-SITE CONSTRUCTION

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Abstract- Off-site construction methods, such as prefabrication and modularisation, offer a means to improve quality and efficiency in the construction sector. Despite numerous investigations into the activity reporting favourable outcomes, including reduction in time requirements, improvements in quality, leaner production, reduction in cost, and improvements in productivity, significant real and perceived barriers to the uptake of off-site construction methods exist. Based on the results of a literature review conducted as part of a doctoral project, this paper presents that cost, lack of flexibility, regulatory uncertainties, and a lack of awareness and expertise generally underpin resistance towards the adoption of off-site construction among clients, financial institutions, and residential construction companies.

Keywords- Engineering project management, literature review, off-site construction barriers

I. INTRODUCTION

Off-site construction methods ('off-site construction') such as prefabrication and modularisation have been championed as novel techniques suitable for improving quality and efficiency in the greater construction sector [1]. The benefits of off-site construction have been reported for a number of decades and include reduction in time requirements, improvements in quality, leaner production, reduction in cost, and improvements in productivity [2], [3]. However, for all of its perceived benefits, there are also significant perceived disadvantages of off-site construction among key stakeholders [4].

These adverse perceptions, in turn, act as barriers to the greater uptake of off-site methods [5]. In fact, a relatively recent study by reference [6] found that representatives from house building companies in the United Kingdom were overwhelmingly more satisfied with traditional onsite methods as opposed to off-site construction methods. Reference [6] found that only 31 per cent of respondents were satisfied with the performance of off-site methods within their own organisations and only 49 per cent were satisfied with the performance of off-site construction in the industry generally. This compares poorly with satisfaction rates of traditional construction methods: in the same study, 82 per cent of respondents were satisfied with the performance of traditional onsite methods in their own organisations and 59 per cent were satisfied with performance across the whole industry.

This indicates that, on balance, off-site construction is most likely still perceived negatively and is seen as being less effective than onsite construction, notwithstanding its widely reported benefits. This paper will report the findings of a literature review concerning barriers to off-site construction which was conducted as part of a doctoral project.

II. INCREASED COST, TIME AND POORER QUALITY

Cost is often perceived as a dominant barrier to increased uptake of off-site construction activities. Increased cost is often considered a consequence of increased time, and poor quality, which are commonly cited issues with respect to off-site construction activities. Cost, which is often simultaneously perceived as a benefit, is believed to be a major barrier to the uptake of off-site construction activities due to the natural tendency for clients, designers, and project managers to act to reduce perceived risks [7]. Perhaps surprisingly, many of the factors which survey respondents cited as being the greatest advantages were also cited as the greatest disadvantages. According to reference [7], poor build quality of pre-fabricated components, incorrect designs, delayed delivery time and the volatile nature of the supply chain are have the potential of impacting adversely on overall cost. In reference [8], aside from cost, the second-largest barrier to clients, designers and contractors was longer lead-in times. Similarly, in reference [9], time issues were reported to be among the top three constraints inhibiting implementation of off-site construction methods. These findings contradict almost entirely the fact that, in the same studies, clients praised the higher quality and consistency of off-site components, as well as the shorter construction time frames, and reduced cost. The reason for this may have to do with inconsistent experiences of off-site construction among the different stakeholders. They suggest that while some off-site construction products from specific vendors may have particular benefits for some projects and stakeholders, other units produced off-site may have negative effects for other projects and stakeholders. Overall, the findings are indicative of the importance of factors such as time, quality and cost to stakeholders

generally, meaning that they will almost always appear near the top of the list in qualitative studies of stakeholder perception.

Reference [7] also investigated what stakeholders in the United Kingdom believed were the disadvantages or issues of off-site production technologies. Responses indicated that prefabricated components could sometimes be poorly built due to the fact that contractors were not experienced enough. Another issue was that the original design of the items had been, for whatever reason, incorrect. Late deliveries of materials and even supplies going into receivership were cited as issues. Stakeholders were also critical of the potential for cost savings in some cases. Some believed that similar outcomes were achievable using conventional methods while others believed that only high volume projects with sufficient repetition applications would worthwhile [7].

In Korea, one study found that using precast concrete and other components produced off-site for the purposes of enhancing productivity and saving cost has largely not been successful in that setting. The authors suggested that traffic control on site, and other costs related to transportation plagued the installation of this prefabricated item [10]. The authors also found that costs related to providing an appropriate clearance area and a temporary stockyard for finished precast concrete led many contractors to avoid off-site construction in Korea [10].

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III. LACK OF FLEXIBILITY AND LIMITED OPTIONS

Lack of flexibility is probably the most easily identifiable barrier to greater uptake of off-site construction activities. In a study by reference [11], architects and engineers held that the inability to make changes onsite and transport restraints were the two major challenges of using off-site construction methods. As reference [12] opine, the geography and low population density of Australia means that transport constraints may be a particular issue for the use of off-site manufacturing in Australia. Particularly perhaps in Western Australia, however somewhat paradoxically mining operations in the remote Pilbara and Kalbarri regions are increasingly being drawn towards modular solutions for the residential units to accommodate mining staff and worker.

Limited design options, related to a lack of flexibility, is another barrier. These three challenges were also most frequently identified by contractors in [11]. The inability to freeze design and specifications early was also cited as the most important hindrance to off-site

construction methods in a study by reference [9]. This same limitation was also expressed by 29 per cent of house building companies in reference [6], constituting the third most significant limitation to the use of off-site construction methods. Similar findings were made in [7]. Grouped under the category of 'availability', the study found that many clients felt that off-site construction presented limited solutions and placed limitations on design. This indicates that, despite its perceived (if contested) advantages in areas such as quality and time, off-site construction cannot always substitute onsite construction. Its inflexibility in some situations means that for many projects it is not always an optimal choice. On the other hand however component supply and installation for uniform design solutions, embraced by mining operations in Western Australia are currently less inclined towards a need for architecturally significant design.

As reference [13] states, there is a tension between the interests of off-site manufacturers and building companies or clients. Particularly in the past few decades, the focus of the construction industry is on delivering customisation rather than standardisation. However, in order to improve manufacturing efficiency and economies of scale, off-site manufacturers have an incentive to minimise variations, limit choices and standardise components. The fact that it is to some extent a naturally occurring economic force makes it a significant limitation of off-site construction. Albeit that arguments towards flexibility and 'freezing designs' onsite are one of the main contributory factors in contracted conflict and related variation and extension their claims.

It is important to note, however, that, as with cost and time, some stakeholders reported increased flexibility and greater customisation options in off-site construction. In reference [8], 33 per cent of clients and designers raised each of these two benefits, while 15 per cent of contractors cited increased flexibility. Reference [14] was also interested in a tradeoff that appeared to be emerging in relation to the uptake of off-site production technologies. While the pair acknowledged that industrialised construction approaches involving the use of prefabricated components tended to lead to greater labour productivity, better quality, lower construction cost, and better on-time delivery, the disadvantage could be a loss of flexibility. In other words, customers would be faced with lower variety and lower flexibility concerning the choice of components for the project. The upshot of this it appears is that off-site production can provide the greatest benefits when economies of scale can be developed. Thus, the use of prefabricated components may be more beneficial for larger scale

projects as opposed to smaller more unique buildings such as detached single houses [14]. Similarly, reference [15] focused on the need for long-term planning. The team found that while stakeholders believed that labour productivity had been increased through the use of off-site production technologies, one consideration that the team alluded to was that the client's design requirements needed to be confirmed in contract much earlier when off-site production technologies are used. This is because of the key decisions concerning the building project will need to be made earlier when prefabrication is intended to be used, and the contractor will probably need to make a substantial commitment to those materials [15].

IV. LACK OF KNOWLEDGE AND REGULATORY GUIDANCE

Legal uncertainties or restrictions have also been cited as a barrier to uptake of off-site construction activities. Studies have suggested that regulation regimes can be barrier to the adoption of off-site construction methods [5]. In reference [11], 11 per cent of contractors and 8 per cent of designers mentioned that local zoning ordinances restricted the use of off-site construction, while 6 per cent of contractors and 9 per cent of designers mentioned that local building regulations restricted the use of off-site construction. A lack of regulatory guidance was a major barrier preventing the full exploitation of off-site construction. According to reference [8], 46 per cent of contractors cited a lack of guidance and information as being a problem, while 23 per cent cited the lack of standards and codes available.

This was the third most significant barrier cited after higher cost and longer lead-in times. Among clients and designers, 33 per cent identified a lack of guidance and information as a barrier, while the same amount mentioned lack of standards and codes.

This issue might be suggested as being linked to clients that seek their own bespoke design rather than an off-the-peg solution already available. A lack of awareness and know-how has also been cited as a barrier to uptake of off-site construction activities. In reference [12], a lack of adequate knowledge was identified as a significant constraints against the adoption of off-site construction methods. Aside from a lack of 'general guidance' regarding off-site construction in the marketplace, another problem was the fact that designers and constructors had limited experience of off-site methods and still often applied traditional onsite ways of thinking. A lack of awareness and expertise in the area of off-site construction is believed to underpin broad stakeholders concerns and the implications of these concerns as addressed following.

V. EVALUATION AND IMPLICATION

A. Stakeholder Resistance

The perception of stakeholders towards off-site construction is a mixed one, with key groups identifying both significant advantages and disadvantages. Nevertheless, as indicated in reference [6] above, there appears to be relatively low satisfaction with off-site construction methods, with only 31 per cent of respondents in that survey being satisfied with off-site methods in their own companies. More broadly, most of the surveys showed that off-site construction methods suffered from stakeholder resistance and a negative image.

Resistance from clients is likely to act as a barrier. In reference [8], 38 per cent of clients and designers reported 'client resistance' to be a major barrier hindering their adoption of off-site construction methods, with 13 per cent identifying it as the main barrier. Since part of the target group of this survey were clients themselves, it may be hypothesised that these findings show that many clients have a self-reported negativity towards off-site construction. Among contractors, 31 per cent found client resistance to a major barrier, with 23 per cent listing it as the most important barrier (the second highest result after increased cost). 28 per cent of clients and designers and 46 per cent of contractors reported that off-site construction had a negative image. Resistance from financial institutions is also likely to act as a barrier. In the study of contractors by reference [11], 31 per cent of respondents noted that among their top three challenges to using off-site construction techniques was the fact that project owners or financial institutions would not allow such techniques to be used. Resistance from residential construction companies is likely to act as a barrier. Reference [6] also discusses the reasons for the low levels of satisfaction towards off-site construction among house builders. They situate the cause in the low level of usage of off-site methods, in a context where builders are supportive of their existing work practices (i.e. traditional onsite construction). Furthermore, as Reference [6] point out, the construction industry is traditionally risk-averse and not an early adopter and there is insufficient knowledge of the benefits of off-site construction. This last point is particularly illustrated by the survey findings, with, for example, many respondents citing cost as a major negative aspect of off-site construction without understanding that in fact off-site methods can reduce costs over the life of the project. Resistance from the construction industry general is likely to act as a barrier. Both reference [12] and [1] found that there was a culture against change in the industry. Reference [12] and [13] propose that the bias against off-site construction may partly be caused by its reputation for standardisation

and the fact that it was used in constructing many affordable housing projects in the 1960s and 1970s. Often clients, particularly in the residential sector, may not be aware of the advantages of prefabrication and modularisation. It was found in a study by Reference [16] that between 39 and 54% of architects indicated that their clients did not want to use these off-site construction technologies.

B. Future Adoption and Value

The aforementioned negative perception of off-site construction does not appear to translate into low future adoption prospects is not, however, indicated by the research. Indeed, in Reference [6], 64 per cent of surveyed house building companies believed that the industry needed to increase its use of off-site construction methods, with larger builders being more favourable towards the increase. While building companies did not favour the use of complete modular buildings, there was significant support for increasing the use of modular kitchens and bathrooms, external walls, timber frame structures and roofs [6]. On a similar note, reference [7] found that 52 per cent of clients interviewed would definitely increase their use of pre-assembly in the future, while only 20 per cent would probably not or definitely not do the same. Finally, in reference [1], 73 per cent of respondents indicated that off-site construction was important to the future of the UK construction industry.

Independently of stakeholder perception, the future growth prospects for off-site construction appear to be moderate. While there is no data for gross output or value added beyond 2008, reference [17] includes a series of forecasts until 2013. According to the forecasts, growth in the off-site construction industry resumed in 2011, although rates of output growth were relatively low – 0.5 per cent per annum in 2011, rising to 3.1 per cent per annum in 2013. This suggests that, in a post-financial crisis world, the off-site construction sector will not see the surging it experienced in the late 1990s and early 2000s, when annual growth rates were often in the double digits [17].

C. Implication

Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as SI, ac, and dc do not have to be defined. The negative perception and resistance that some stakeholders have towards off-site construction appears to be one a factor holding back its growth. As reference [6] suggests, one of the main ways of increasing growth is to make stakeholders recognise fully and engage with the potential benefits of off-site construction. Towards this end a greater focus on objective research on the

identification, measurement and monitoring of the variables that differentiate off-site construction, from more traditional in situ supply and installations activities which can then be used to guide industry in the off-site methods can add value to a project and in particular seek to address explicitly performance variables. As pointed out previously and noted by reference [12], while there is a significant body of literature on case studies and stakeholder perceptions of off-site construction, there is little objective comparison between it and off-site construction and more importantly that objectively clarifies performance variables identification and measurement in off-site work. In particular, as reference [13] state, more research needs to be carried out to assess the cost of off-site construction relative to onsite construction; in other words performance factors. The confused perception of cost that most stakeholders have can only be conclusively addressed through comprehensive objective research in this regard. reference [6] recommends a number of other possibilities for the future: improving procurement, providing better cost data and comparative costing methods, reforming the planning process and improving knowledge on the decision-making process and site integration of off-site construction methods. Reference [12] state that more research should be conducted into how manufacturing principles from other industries, such as steel, chemicals and machinery, can be applied to the construction industry. They note that principles from other manufacturing industries have successfully been applied to off-site construction of homes in Japan. This point, which is often ignored, is a highly valuable one. Insights from more established manufacturing industries and their means to measure performance through operational management can ensure that off-site construction, a relatively young and local industry, has opportunities to develop perhaps in an efficient and productive way. This would add value to guidance in the utilisation of off-site construction. Despite the promise offered some advocates of off-site construction methods, reference [18] notes that a total or even predominant switch to standardisation and prefabrication is untenable. Instead, he argues that the focus should be on optimisation rather than maximisation of use [18]. Similarly, reference [13] states that off-site construction 'is not, and is unlikely to become, a universal construction solution for all built assets. Instead, stakeholders should focus on determining the appropriate use of off-site construction, finding areas where the advantages of off-site construction can add the most value and where opportunities for continuous improvement exist. For example, off-site construction, due to its more precise and fast time frames, may add a lot of value to projects that need a more standardised and uniform design solution to a repetitive

(non-complex) design brief, to be completed by a fixed time, but may not be so useful in circumstances where this is not an important factor.

This reflects the findings of the studies which showed both that off-site construction was limited through its lack of flexibility as well as the fact that the very benefits of off-site construction in some circumstances can also be its biggest disadvantages in other circumstances. In this way, the focus shouldn't be on promoting growth in off-site construction at all costs, but rather in finding out where off-site construction is most effective and seeking to optimise objectively its performance parameters in that area.

CONCLUSION AND FUTURE RECOMMENDATION

Perceptions concerning cost, lack of flexibility, regulatory uncertainties, and a lack of awareness and expertise generally have been found to underpin resistance towards the adoption of off-site construction. Clients, financial institutions, and residential construction companies have each been identified as groups most concerned about potential risks associated with the use of off-site construction methods. Yet as noted, negative perceptions concerning these methods does not necessarily mean that future adoption prospects should be low. Increased expertise is required in the area of off-site construction, and knowledge concerning the practice needs to be made available to stakeholders. With an increased understanding of the potential of off-site construction methods the aforementioned barriers can be to a large extent overcome.

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